Attorney Docket No. 022163-000110US

PATENT APPLICATION

UNIFIED IMAGE PROCESSING SYSTEM

Inventor: George W. Dalke, a citizen of The United States, residing at
1247 Pitman Avenue
Palo Alto, CA 94301

Entity: Small

TOWNSEND and TOWNSEND and CREW LLP
Two Embarcadero Center, Eighth Floor
San Francisco, California 94111-3834
Tel: 650-326-2400

UNIFIED IMAGE PROCESSING SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 60/448,080, filed February 20, 2003 for Unified Image Processing System, the entire disclosure of which is incorporated by reference for all purposes.

ATTACHED DOCUMENTS PART OF THIS APPLICATION

[0002] The following documents are attached to this application and are considered part of this application:

1. Copy of U.S. Provisional Patent Application No. 60/448,080, filed February 20, 2003 for Unified Image Processing System. 16 pages.
2. HTML user interface example. 1 page.
3. HTML user interface example source code. 10 pages.
4. Text Form user interface example. 1 page.
5. Parameter Array File Diagnostic Form. 1 page.
6. Text Form user interface to Parameter Array File source code. 10 pages.
7. Parameter Array composition source code. 7 pages.
8. Parameter Array to Diagnostic Form source code. 9 pages.
9. Parametric Image Transform Execution source code. 17 pages.
10. "Parametric Transforms." 4 pages.

BACKGROUND OF THE INVENTION

[0003] During image processing and manipulations, problems with processed images, which are referred to as pathologies, arise. In most cases, it is up to the user to avoid pathologies by visual feedback and interactively moving a control to adjust the amount of processing tolerated by a particular image. The control settings are generally a compromise between increasing the desirable results and keeping the pathologies acceptably low.

[0004] Some examples of image pathologies are as follows. A typical "sharpen" filter causes halo and outlining effect, and may further enhance jpeg artifacts, particularly in relatively uniform areas such as sky. Further, burn out and color shift are often caused by brightness adjustment. Posterization and localized color shifts are caused by excessive processing. Textured objects are "flattened" by low local contrast in part of the transform.

SUMMARY OF THE INVENTION

[0005] According to one aspect, the invention provides an image processing method that comprises generating a synthesized image transform from a set of synthesizing parameters; and subjecting the input image to the synthesized image transform to form an output image wherein: the synthesized image transform is generated from a set of synthesizing parameters; the synthesizing parameters have a defined domain of allowed values; the complete set of synthesized transforms is obtained by varying the synthesizing parameters over all values within the domain; the visual effect of each synthesized transform is characterized by a set of visual effect parameters; and the visual effect parameters and the synthesizing parameters are related in that the visual effect parameters are generated from the synthesizing parameters for the complete set of transforms, and/or the synthesizing parameters are generated from the visual effect parameters for the complete set of transforms.

[0006] In some embodiments, the synthesizing parameter sets are composable (that is, a function or algorithm combines two or more sets of synthesizing parameters into a single set of synthesizing parameters); and the composed synthesizing parameters are sequentially equivalent (that is, an image processed sequentially by two or more synthetic transforms will be equivalent to an image processed through a single transform which has been synthesized from the synthesizing parameter set composed from the synthesizing parameter sets of the sequential transforms).

[0007] Embodiments of the invention are capable of eliminating or significantly reducing pathologies, while simplifying the optimization of images, thereby removing the need for experienced operators and interactive controls. The transforms also produce superior images without degrading the data from the original image. This feature allows an image to undergo further processing, while eliminating the occurrence of further pathologies.

[0008] A further understanding of the nature and advantages of the present invention may be realized by reference to the remaining portions of the specification and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 shows an image transform;

[0010] FIG. 2 shows a parametric image transform;

[0011] FIG. 3 shows image visual effect functions and parameters;

[0012] FIG. 4 shows transform visual effect parameters;

[0013] FIG. 5 shows transform parameter set and visual effect parameter set conversion;

[0014] FIG. 6 shows composing a sequence of parametric transforms into a single transform;

[0015] FIG. 7 shows scalar composition;

[0016] FIG. 8 shows simulation of a sequence of arbitrary transforms;

[0017] FIG. 9 shows the simulation of a sequence of arbitrary transforms;

[0018] FIG. 10 shows the synthesis of a sequence of visual intents;

[0019] FIG. 11 shows the execution of a selective image transform;

[0020] FIG. 12 shows the derivation of a v-array; and

[0021] FIG. 13 shows a program/file overview.

DESCRIPTION OF SPECIFIC EMBODIMENTS

[0022] FIG. 1 shows an image transform. Page 5 of the Provisional Application, section "Fundamental Definition and Algorithms," subsection "Image transform" presents a notation for an arbitrary image transform. Note that the notation $\mathbf{x}' = t(\mathbf{x})$ is equivalent to:

$$r' = t_r(r,g,b)$$
$$g' = t_g(r,g,b)$$
$$b' = t_b(r,g,b)$$

[0023] FIG. 2 shows a parametric image transform. Page 8 of the Provisional Application, section "Fundamental Definition and Algorithms," subsection "Parametric transforms" presents

the notation and definition for a parametric transform. We also refer to a parametric transform as a "synthesized" transform.

[0024] FIG. 3 shows image visual effect functions and parameters. Page 7 of the Provisional Application, section "Fundamental Definition and Algorithms," subsection "Analytic selective transforms" presents the notation and definition for a set of analytic selective functions. The selective functions are also referred to as visual effect functions.

[0025] Associated with each selection function is a "visual effect" given by a set of visual effect parameters. Each visual effect parameter is the statistical expected value of the visual effect functions, given by the equation

$$V = \langle f \rangle = \iiint f(r,g,b)\ p(r,g,b)\ dr\ dg\ db$$

where p(r,g,b) is the joint probability distribution of the input image.

[0026] FIG. 4 shows transform visual effect parameters. The definition of the visual effect parameters is given by an image probability distribution. Since the probability distribution of the output image can be calculated directly from the transform, we can associate the visual effect parameter with the transform for a given input. By definition, the output visual response parameter is

$$V' = \iiint f(r',g',b')\ p'(r',g',b')\ dr'\ dg'\ db'$$

We can calculate the output probability distribution from the transform and the input probability distribution as

$$p'(r',g',b') = p(t_{inv}(r',g',b'))$$

[0027] Introducing a change of variables, we get

$$V' = \iiint f(t(r,g,b))\ p(r,g,b)\ dr\ dg\ db$$

This remarkable results allows us to associate the visual effect parameters with a transform and an input image. For the special case that the input image has uniform probability distribution, the uniform visual effect parameter for a transform is given by:

$$Vt = \iiint f(t(r,g,b))\ dr\ dg\ db$$

[0028] FIG. 5 shows transform parameter set and visual effect parameter set conversion. This drawing shows the derivation of two estimator functions. The first estimates the visual parameters as a function of the synthesis parameters, and the second estimates the inverse function, the synthesis parameters as a function of the visual parameters. Associated with each estimate is an error measurement and the estimators are selected to minimize the error.

[0029] FIG. 6 shows composing a sequence of parametric transforms into a single transform. This drawing shows the method of combining a sequence of parametric transforms into a single parametric transform. First, a v-array is constructed consisting of the set of p-arrays for each transform in the sequence. The reduction algorithm on page 13 of the Provisional Application, p = K(V) reduces the v-list to a p-list. This p-list is used to synthesize an equivalent transform.

[0030] FIG. 7 shows scalar composition. Page 7 of the Provisional Application, section "Fundamental Definition and Algorithms," subsection "Analytic selective transforms" presents the notation and definition for a set of analytic selective functions. In most of the figures, the selective functions are equivalent to the visual effect functions.

[0031] FIG. 8 shows simulation of a sequence of arbitrary transforms. This drawing shows a sequence of arbitrary transforms used to process an input image to an output image. It is desired to find a single transform that has the equivalent results as the sequence of transforms. This method calculates the visual effect parameters for the output image, estimates the corresponding p-array using the estimator in FIG. 5, and synthesizes a parametric transform.

[0032] FIG. 9 shows the simulation of a sequence of arbitrary transforms. The method shown in FIG. 8 requires that an output image is obtained and used to calculate the visual effect parameter array. FIG. 9 shows a method where the output image is not required. In this figure, the visual effect parameters for each transform are measured, then used to estimate a corresponding p-array. The resulting set of p-arrays forms a v-array which uses the reduction algorithm, **p** = K(**v**) (page 13 of the Provisional Application) to derive the corresponding p-array which is used to synthesize and equivalent transform.

[0033] FIG. 10 shows the synthesis of a sequence of visual intents. The method shown in FIG. 9 requires that the output visual effect parameters from each of a sequence of transforms be

calculated or measured. In this figure, the user simply specifies the desired visual effect parameters for each stage. From this a transform is synthesized as in FIG. 9.

[0034] The specification of the desired visual effect parameters is facilitated by using the "Unified User Interface" presented on page 14 of the Provisional Application. Note that that using a sequence of visual intents gives an intuitive and powerful method of specifying very complex transforms. This is a significant aspect to the authoring and editing capabilities set forth in the Provisional Application.

[0035] FIG. 11 shows the execution of a selective image transform. Page 13 of the Provisional Application, section "Fundamental Algorithms for an Image Processing System," subsection "Execution" states the following equations for calculating a v-array.

$\mathbf{x}' = t(K(G(S(\mathbf{x}),\mathbf{v})), \mathbf{x})$, where

$\mathbf{x}$ = an input pixel value, typically $\mathbf{x} = (r,g,b)$

$\mathbf{x}'$ = an output pixel value, $\mathbf{x}' = (r',g',b')$

t is the parametric transform

$\mathbf{v}$ is a v-list consisting of n p-list structures

$S(x) = (s_1(x),\ldots,s_n(x))$ is a complete set of fundamental selectors

G is the scalar combination algorithm

K is the reduction algorithm that maps V into a p-list

[0036] FIG. 12 shows the derivation of a v-array. Page 13 of the Provisional Application, section "Fundamental Algorithms for an Image Processing System," subsection "Combining processes at execution time" derives the equations for calculating a v-array.

[0037] The algorithm for combining the q-array to a single v-array for execution is

$V = K(G(A,Q)$, where

G is the scalar combination algorithm

K is the reduction algorithm that maps Q into V

The combined execution transform thus becomes:

$$x' = t(K(G(S(x), K(G(A,Q))), x)$$

[0038] While the above is a complete description of specific embodiments of the invention, the above description should not be taken as limiting the scope of the invention as defined by the claims.